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ABSTRACT

A manipulandum-referenced taxonomy for response categories appropriate to primary education is presented. The tenability of automatic on-line evaluation of the different types of response when processing equipment of the sort that probably will be available to Southwest Regional Laboratory is preliminarily evaluated. (Author/SK)

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ABSTRACT

A manipulandum-referenced taxonomy for response categories appropriate to primary education is presented. The tenability of automatic on-line evaluation of the different types or response when processing equipment is of the sort that most probably will be available to SWRL during the next year or so is preliminarily evaluated.

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ON-LINE IDCMS EVALUATION OF DIFFERENT CATEGORIES OF RESPONSE

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Whether on the basis of its own Version 1 capabilities or in consequence of augmentation based on core-to-core interfacing and use of supplemental terminals, we wish in time to transform the SWRL Instructional Development Control and Monitoring System (IDCMS) into one whose student-system interactive capability is not bounded by the category of response employed. This paper presents a taxonomy for response categories appropriate to primary education and preliminarily assesses the degree to which we can expect such a system soon to perform interactively as a function of response category. If we can visualize a relatively straightforward way of arming the system both to accept responses of a given category and to evaluate them on-line against a criterion for response acceptability, a preliminary view can be taken that the system has or can be made to have an interactive capability referencing to that response category. Otherwise, such capability will be realized only following extensive and perhaps costly effort. Unsurprisingly, the general conclusion is reached that those response categories whose responses cannot yet be on-line machine evaluated pose a greater challenge to linguists and semanticists than to those whose efforts reference to hardware design.

For present purposes, the taxonomy of response categories can be viewed as grounded upon three mutually-exclusive and, taken together, exhaustive superordinate categories. These are: a) motor responses

using characters or codes (keyboard-referenced), b) voice responses (microphone-referenced), and c) spatial motor responses. In this system, motor and voice categories contrast. Hence, a visual tracking response would class as a motor response, since it clearly is not a voice response. Physiological responses below the molar motor level are not of present interest.

Motor Responses Using Characters or Codes

IDCMS is most clearly applicable to student-system interactive use when the response is formed on a keyboard containing alphanumeric characters and supplementing commands and codes. Three subcategories of such responses are distinguished.

Surface syntactic constructed response. Any phrase or sentence or unordered, semiordered, or ordered set of phrases or sentences which a test item invites and given instruction, if effective, constrains will class here if made through an alphanumeric or similarly coded keyboard. Sequential responses to complex arithmetic problems--e.g., response sequences which show steps enroute to problem solution--also class here. On-line processing of a surface syntactic constructed response presupposes existence of an effective parsing program (and perhaps augmenting programs addressing semantic and set-relational problems). Oversimply perhaps, the system will have to reduce the response to a "base" form and to compare this base form with a criterion base form response retrieved from an auxiliary store. While on-line processing of responses of this type are hardly a "no sweat" proposition, SWRL's Language Analysis Package effort currently is appreciably addressing the problem. It appears not imprudent to assume that we

will be able to impute to IDCMS an on-line evaluative capability regarding an appreciable portion of such responses before too much longer, whether on the basis of Version 1 configuration of the system or in consequence of augmentation of the system's processing capability using a suitable auxiliary processer.

Alphanumeric item constructed response. Responses to simpler arithmetic problems, word-spelling responses, and item or concept naming responses will class here. Whatever the criterion response characteristics regarding accuracy or speed, on-line evaluation of such responses appears to pose no insurmountable challenge to software designers. Moreover, it should be possible to cause the system to model or shape such response sequences by progressively unblocking the next correct keypress in the sequence and, if desired, backlighting it. The alphanumeric item constructed response is the type of constructed response that the system can be made to on-line evaluate most easily.

Selected response. Constructed motor response options are constrained only by instructional effectiveness and surface alternatives inherent in syntax or mathematical structure. Selected response options are more narrowly constrained by the test item. The response must be selected from a sharply-constrained field--e.g., the alternatives of a multiple-choice item. Typically, such responses will be made by depressing a single key, whether alphanumerically coded or color or picture coded. Typically also, a portion of the keyboard will be blocked off for use in making such responses. The keyboard originally proposed for IDCMS was such a reduced keyboard--one consonant with making selected responses to multiple-choice items.

The selected response need not be restricted to a single keypress. Some interactive systems compel S to use a sharply-reduced vocabulary and syntax for purposes of interacting with the system. Often in such situations, the effect is to restrict S's response to one of a few alternatives--e.g., CORRECT, WRONG, DON'T KNOW. Even though S may have to learn the perceptual-mechanical skills underlying loading such responses into the keyboard, the responses themselves class as selected rather than constructed in the present context because a constructed response is constrained only by instructional effectiveness and structure of an interaction language of nontrivial complexity. That is, we call responses constructed only if ineffective instruction makes a large set of response alternatives entertainable. If the set of entertainable response alternatives must be small even though instruction is ineffective, then the response classes as selected. On-line evaluation of selected responses made through a keyboard appears well within IDCMS capabilities.

Voice Responses

The speech and speech element responses classed under this heading parallel motor responses using characters and codes excepting that input into a "written-form" analyzer must be output from a speech analyzer. This heading also subsumes trained voice responses--whether in the sense of diction or of music.

Surface syntactic speech response. Evaluation of speech responses at the syntactic level presumes everything that evaluation of motor responses at this level presumes and, in addition, a front end analysis

performed by a speech analyzer that transform spoken into written form. It is probable that on-line evaluation of speech responses at the syntactic level will not be performed by IDCMS either in Version 1 configuration or in an augmented configuration that we can obtain soon. The alternative is to have E rather than the system perform real-time evaluation and to signal the result to the system. To the extent that E can do this quickly and reliably, then the E-augmented system gives us on-line evaluative capability regarding such responses.

Alphanumeric item speech response. Comments made immediately above apply. Letter sounds form an important subclass of the responses that class here. While on-line evaluation of responses of this subcategory by IDCMS seems a less challenging requirement than system on-line evaluation of speech responses at the syntactic level, here too the prognosis for automatic on-line evaluation very soon is not an optimistic one. Again, the E-augmented system can be used to achieve on-line evaluation during earliest use of IDCMS.

Selected speech response. This mode of responding simply is alternative to motor responding through a keyboard under the selected response condition. Having such a capability might prove desirable if it can be obtained cheaply. As an alternative to on-line evaluation using the E-augmented system, SWRL engineering staff might seek to design a sharply-constrained speech analyzer (if a cheap shelf item does not exist) which would discriminate between the voiced items of such series as 1, 2, 3, 4, 5 and white, black, red, green, pink. Such a device really would be a speech pattern discriminator rather than a speech analyzer.

Trained voice response. Whether this is a diction or music type response, the essential feature of the response is that it should match a standard. Perhaps this simply comes down to a comparison of two frequency x amplitude plots, one provided by S and one contained in system storage, with departure from standard guaged against allowable departure from standard. It is probable that early capability for on-line evaluation of such responses comes down to how finely differences between response and standard are to be discriminated. SWRL engineering staff has invested preliminarily in the problem. It appears tenable that on-line evaluation at least of certain types of musical response could be obtained early in the life of the system.

Spatial Motor Responses

We distinguish between drawing and tracking spatially-referenced responses and between "freeboarded" and "keyboarded" drawing responses.

Freeboard-referenced drawing responses. The RAND Tablet and devices currently in prototype at the University of Illinois, University of Pittsburgh, and elsewhere exemplify required hardware. Functionally, this is a terminal whose response area is a flat two-dimensional surface such that stylus-writing on the surface will bring that portion of the surface into contact with a sensing surface. Such devices permit copying responses, free form drawing responses, and intermediate responses. The mechanical analogue, for those unfamiliar with these devices, is the "blackboard" toy wherein a child applies a wood stylus to waxed paper over a black tarlike material. Following composition on such a device, it is returned to the preresponse state.

If a pattern is placed on the writing surface (in proper alignment), then a copying response can be evaluated on-line against a criterion for absolute or average permissible departure from pattern. Such patterns might include line drawings exemplarizing concepts, letters, or words. Given such a terminal, then on-line evaluation of copying responses should pose no insurmountable challenge to software designers.

However, if we allow the response to be free form, then on-line evaluation becomes a problem in pattern recognition. On-line system evaluation of free form drawing or printing responses should pose a considerable challenge for software designers, assuming that hardware in present or quickly-attainable form is up to the requirement. To the extent that on-line evaluation of free form responses by the system itself is not presently feasible, we can again fall back on the E-augmented system, which will be able to function in the desired way if E is sufficiently quick and reliable.

Intermediate to copying and free form responses are relational responses that reference to a pattern but do not involve copying the pattern. An illustration is the diagonal drawing response. A constraining square or rectangular outline is provided and S is required to line a diagonal--with or without a constraint on orientation--through the pattern. Similarly, one might provide S with the outline of a human face in front view and require placement of eyes, nose, and mouth. In this instance, we could avoid a pattern recognition requirement by having responses judged on placement rather than shape. Intermediate responses seem as capable of on-line evaluation as copying responses.

Keyboard-referenced drawing response. Imagine a terminal whose response area is an x, y matrix of keys elevated above a flat two-dimensional surface. Keys should be backlightable by the system or by S responding under system-defined conditions and desirably alternatively backlightable using different colors of light. Such a keyboard could be used either to require S to provide matrix-constrained free form exemplars of geometric concepts--probably with scale constraint imposed--or to complete partially patterned exemplars of such concepts. It is apparent that criteria for sequencing keypresses could be applied--e.g., that the diagonal be constructed progressively left to right. Given such a terminal, on-line evaluation of responses appears to pose no insurmountable challenge to software designers.

Tracking response. Tracking responses can be referenced to various sorts of terminal displays and to various sensorimotor modalities. The pursuit rotor tracking response is illustrative. Time on target is one measure of pursuit rotor proficiency. On-line evaluation of such responses appears to pose no insurmountable challenge to software designers.

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Recursive and combinatorial usages of the foregoing categories will yield more involved responses. A child asked to order a set of pictures or sentences to tell a story will select an order and perform a response sequence that indicates the order selected. An identification response may take either selected or constructed response form. While a time-pressured identification response--e.g., at tachistoscopic

levels--may necessitate finer resolution than a CRT provides and perhaps shorter interval exposure times than the system finds convenient, the required augmenting devices are shelf items and required software efforts do not seem undue. Discrimination threshold studies similarly might require special peripheral equipment but would turn up no new forms of response as responses are defined above--which is in terms of manipulanda. Responses signifying "There it is" or "I see it now" lend themselves readily to keypress expression. Where latency of such a motor response adds undesirably to a duration of interest, S's mean latency can be evaluated and the system can be required to take this out of all such durations.

The test, then, of the taxonomy presented above is not whether one can come up with responses whose names or sensorimotor involvements are different than the names and molar forms used as exemplars above but rather whether one can come up with responses requiring different sorts of manipulanda than those cited above. In this connection, the tracking response category contemplates various sorts of unnamed peripheral equipment--for example, an eye movement camera if visual tracking or information searching is to be studied.